International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Mechanical Behavior of Concrete Containing Copper Slag and Granite Powder as Alternative Fine Aggregates

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Abstract

Concrete is the most popular building material in the world. It is the most consumable material after water. Concrete is a mixer of binding material, fine aggregate, coarse aggregate and water. Generally Ordinary Portland Cement (OPC) is used as a binding material, Hard Broken Granite (HBG) stone is used as a coarse aggregate and River sand has been the most popular choice for the fine aggregate component of concrete in the past, but overuse of these materials has led to environmental concerns, the depleting of securable Natural resource deposits and a concomitant price increase in the material. As environmental and cost concerns Industrial waste or industrial by products can be used as a partial or full replacement of natural resources. The present, study concerns with the partial replacement of fine aggregate in conventional concrete. The reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute material to sand as fine aggregates in the production of concrete. Various type of materials can be used for replacement in fine aggregate. In which, some of the materials are Copper slag, Granite powder, Granulated blast furnace slag, Washed bottom ash, Quarry dust, Foundry sand, Spent fire bricks, Sheet glass powder, Construction and demolition waste, etc. In present study copper slag and granite powder can be used as a partial replacement of sand. Granite stone powder, a by-product from the cutting process of granite stone used for flooring is one of such materials. Copper slag is a by-product obtained during the matte smelting and refining of copper. The reduction in waste generation by manufacturing value-added products from the granite stone waste will boost up the economy of the granite stone industry. The utilization of granite powder and copper slag in high performance concrete could turn this waste material into a valuable resource with the added benefit of preserving environment. At the same time Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement or as a substitute for fine aggregates since it is available in large quantity from the world copper industry. In recent days there were also been many attempts to use Fly Ash, an industrial by product as partial replacement for cement to have higher workability, long term strength and to make the concrete more economically available. Here it was attempted the use of Pozzolana Portland Cement (PPC) instead of Ordinary Portland Cement (OPC). This present work is

also an attempt to use Granite powder and Copper slag as partial replacement for Sand in M25 grade concrete. Attempts have been made to study the properties of concrete and some properties of Granite powder and Copper slag, their suitability of those properties to enable them to be used as partial replacement materials for sand in concrete.

Keywords: rice hush Ash , PPC,OPC

1. Introduction

Concrete is one of the most durable building material and have high compressive strength compared to other building materials. It provides superior fire resistance compared with wooden construction and gains strength over time. Structures made of concrete can have a long service life. Concrete is widely used material than any other manmade material in the world. As of 2014, about 9.8 billion cubic meters of concrete are made each year, more than one cubic meter for every person on Earth.

Concrete is a non-homogeneous material. It consists of cement, sand and mixed with water. The cement and water form a paste or gel which coats the sand and aggregate. When the cement has chemically reacted with the water (hydrated), it hardens and binds the whole mix together. The initial hardening reaction usually occurs within a few hours. It takes some weeks for concrete to reach full hardness and strength.

Aggregate is the important constituent in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregate is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Aggregate serves as reinforcement to add strength to the overall composite material. Aggregates are divided into two categories from the consideration of size (i) coarse aggregate and (ii) fine aggregate. The size of aggregate is bigger than 4.75mm is considered as coarse aggregate and whose size is 4.75mm and less is considered as fine aggregate. Hard Broken Granite stone is most commonly used coarse aggregate material and river sand can be used as fine aggregate material in conventional concrete.

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. The composition of sand varies, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO2), usually in the form of quartz. Only some sands are suitable for the construction industry, for example for making concrete.

COPPER SLAG:

Copper slag is one of the material for sand replacement material. It is an industrial by- product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tonnes of copper slag is generated. It has been estimated that approximately 24.6 million tons of slag are generated from the world copper industry

Fig: Copper slag sample in dump yard

GRANITE POWDER:

Granite powder is one of the replacement material for natural sand in concrete. Marble and granite industry has grown significantly in the last decades with the privatization trend in the early 1990s, and the flourishing construction industry. Accordingly, the amount of mining and processing waste has increased. Stone waste is generally a highly polluting waste due to both its highly alkaline nature, and its manufacturing and processing techniques, which impose a health threat to the surroundings.

Granite powder, one of the byproducts in granite stone crushing process, not being used for replacement material for river sand in concrete. The granite waste generated by the stone crushing industry has accumulated over the years. Only insignificant quantities have been utilized and the rest has been unscrupulously dumped resulting in environmental problems. Presently, all the processing units are disposing this industrial waste by dumping it in open yards, that nearly occupying 25% of the total area of the industry.

Fig: Granite powder sample in dump yard

2. Literature Review

Literature Review On Copper Slag:

Many researchers have investigated worldwide on the possible use of copper slag as a concrete aggregate. Some of the important and published works are reviewed and presented briefly below.

R RChavan& D B Kulkarni (2013) [17] conducted experimental investigations to study the effect of using copper slag as a replacement of fine aggregate on the strength properties and concluded that Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag and flexural strength increased by 14 % for 40 % replacement.

Al-Jabri et al (2011)[1]investigated the performance of high strength concrete made with copper slag as a replacement for fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of High Strength Concrete made with copper slag. They observed that the water demand reduced by about 22% for 100% copper slag replacement. The strength and durability of High Strength Concrete improved with the increase in the content of copper slag of upto 50%. However, further additions of copper slag caused reduction in the strength due to increase in the free water content in the mix. Also, the strength and durability characteristics of High Strength Concrete were adversely affected by the absence of the super plasticizer from the concrete paste despite the improvement in the concrete strength with the increase of copper content. The test results also show that there is a slight increase in the density of nearly 5% with the increase of copper slag conte0nt, whereas the workability increased rapidly with increase in copper slag percentage.

Literature Review On Granite Powder:

Shirule P.A et al (2012) [20] determined the compressive strength and split tensile strength of concrete in which cement was partially replaced with marble dust powder (0%,5%,10%,15%, 20%).The result indicated that the Compressive strength of concrete increased with addition of waste marble powder up to 10% replaced by weight of cement and further addition of waste marble powder was found to decrease the compressive strength. The optimal percentage replacement was found to be 10%.

Baboo Rai et al (2011) [4] investigated the effect of using marble powder and granules as constituents of fines in concrete by partially reducing quantities of cement as well as other conventional fines. The values of workability, compressive strength and flexural strengths were found. Partial replacement of cement and usual fine aggregates with varying percentage of marble powder (0%,5%,10%,15%,20%) and marble granules revealed that increased waste marble powder (WMP) or waste marble granule (WMG) resulted in increase in workability and compressive strength of mortar concrete.

BouzianiTayeb et al (2011) [7] studied the effect of marble powder content (MP) on the properties self compacting sand concrete (SCSC) at fresh and hardened states. Values of slump flow, the V-funnel flow time and viscosity were found on fresh concrete. At the hardened state, the 28th day compressive strength was found. The obtained test results showed that larger MP content in SCSC (350 kg/m3) improved the properties at fresh state by decreasing V funnel flow time (from 5s 1.5s) and increasing the slump flow values (from 28cm to 34cm). With the use of 250 kg/m3 of MP, the highest initial viscosity

was obtained while retaining good fluidity at high rotational speeds compared to the MP contents of 150 kg/m3 and 350 kg/m3. The 28 days compressive strength decreased with an increase of MP content

3. Experimental Study

MATERIALS USED:

In the present experimental investigation, Industrial waste granite powder and copper slag are used as the partial replacement of fine aggregate and also Portland Pozzolana cement is used instead of Ordinary Portland Cement in concrete mixes. Replacing fine aggregate with granite powder, copper slag and combined replacement of copper slag and granite powder of different weight percentages. The details of materials used in this work are as follows.

CEMENT:

I) PORTLAND POZZOLONA CEMENT:

Portland-pozzolana cement can be produced either by grinding together Portland cement clinker and pozzolana with addition of gypsum or calcium sulphate or by intimately and uniformly blending Portland cement and fine pozzolana.

Portland-pozzolana cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters than normal Portland cement. Moreover, it reduces the leaching of calcium hydroxide liberated during the setting and hydration of cement. It is particularly useful in marine and hydraulic construction and other mass concrete structures.

AGGREGATE:

Aggregate are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Earlier, aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active and also that certain aggregate exhibit chemical bond at the interface of aggregate and paste. The mere fact that the aggregates occupy 70-80% volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable. To know more about the concrete it is very essential that one should know more about the aggregates which constitute major volume in concrete.

4. Experiment Results

COMPRESSIVE STRENGTH STUDIES:

For Compressive strength test standard cube size of 150mm x 150mm x 150mm are used. An average of three specimens are taken for all mixes after a curing period of 7 days , 28 days,56 days and 90 days. The cubes are taken out from the curing tank after attaining days of curing .AS per IS 516-1969.

Fig: Compression Strength test set up

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Table: MeanCompressive strength of M25 grade concrete:

Mix Designa--tion	Cement used PPC	Fine Aggre--gate Used	Percentage replacement in Fine Aggregate		Coarse aggrega--te Used	Compres--sive Strength at 7 days 2 N/mm	Compres--sive Strength At 28 days N/mm2	Compres--sive Strength at 56 days N/mm2	Compres--sive Strength at 90 days N/mm ^{2}
			Copper slag	Granite powder					
M0	100%	100%	-----	-----	100%	15.22	31.80	33.8	35.4
MC15	100%	85%	15%	-----	100%	14.56	31.75	32.75	34.63
MC30	100%	70%	30%	-----	100%	15.63	32.04	34.16	35.78
MC40	100%	60%	40%	-----	100%	16.06	32.78	34.82	36.77
MG15	100%	85%	-----	15%	100%	15.04	28.65	30.66	32.19
MG30	100%	70%	-----	30%	100%	15.48	31.96	34.2	35.66
MG40	100%	60%	-----	40%	100%	15.96	32.25	34.8	35.93
MCG30	100%	70%	15%	15%	100%	15.84	24.85	26.6	27.92
MCG60	100%	40%	30%	30%	100%	15.71	30.08	32.2	33.78
MCG80	100%	20%	40%	40%	100%	18.10	33.43	35.75	37.51

FLEXURAL STRENGTH STUDIES:

For Flexural strength test standard prism of size 100mm x 100mm x 500mm are used. An average of 3 specimens is taken for all mixes after a curing period 7 days , 28 days,56 days and 90 days.For testing of beams the bearing Surfaces of the supporting and loading rollers shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen was placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould along two lines spaced 20.0 or 13.3 cm apart. The axis of the specimen is carefully aligned with the axis of the loading device.

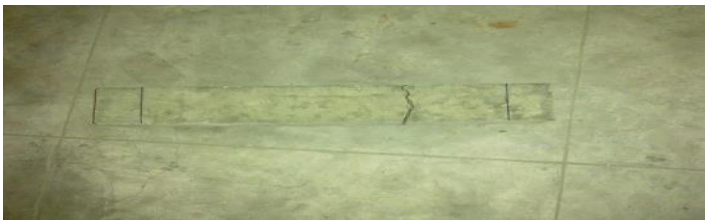

Fig:Flexural Strength Test

Table: Mean Flexural strength of M25 grade concrete:

Mix Designation	Cement used PPC	Fine Aggre--gate Used	Percentage replacement in Fine Aggregate		Coarse aggreg--ate Used	Flexural strength at 7 days N/mm 2	Flexural strength at 28 days 2 N/mm	Flexural strength at 56 days N/mm 2	Flexural strength at 90 days N/mm 2
			Coppe r slag	Granite powder					
M0	100%	100%	-----	-----	100%	2.62	4.01	4.27	4.46
MC15	100%	85%	15%	-----	100%	2.74	4.08	4.33	4.52
MC30	100%	70%	30%	-----	100%	2.78	4.14	4.42	4.57
MC40	100%	60%	40%	-----	100%	2.82	4.20	4.5	4.73
MG15	100%	85%	-----	15%	100%	2.73	3.96	4.23	4.44
MG30	100%	70%	-----	30%	100%	2.67	3.86	4.11	4.3
MG40	100%	60%	-----	40%	100%	2.93	4.24	4.53	4.74
MCG30	100%	70%	15%	15%	100%	4.53	6.89	7.37	7.75
MCG60	100%	40%	30%	30%	100%	4.30	6.50	6.95	7.22
MCG80	100%	20%	40%	40%	100%	4.12	6.17	6.58	6.86

5. CONCLUSIONS

1. Maximum Compressive strength of concrete increased by 3.08% at 40% replacement of fine aggregate by copper slag, and up to 40% replacement, concrete gain more strength than control mix concrete strength, except 15% replacement copper slag concrete.
2. It is observed that for all percentage replacement of fine aggregate by Copper slag the flexural strength of concrete is more than control mix.
3. It is observed that, the flexural strength of concrete at 28 days is higher than design mix (Without replacement) for 15% replacement of fine aggregate by Copper slag, the flexural strength of concrete is increased by 1.74%. This also indicates flexural strength is more for all percentage replacements than design mix. However, for 40% replacement of fine aggregate by Copper slag concrete gives the maximum strength than control mix.
4. Compressive strength and flexural Strength is increased due to high toughness of Copper slag.The compressive strength has increased by 1.41% with the use of 40% replacement of fine aggregates

with granite powder. concrete gain more strength than control mix concrete strength, except 15% replacement of granite powder concrete

5. It is observed that, the flexural strength of concrete at 28 days is higher than design mix (Without replacement) for 40% replacement of fine aggregate by Granite powder, the flexural strength of concrete is increased by 5.73%. It shows that 40% replacement of granite powder gives the maximum flexural strength, than remaining percentage replacements.
6. The split tensile strength has increased by 13.08% with the use of 40% replacement of fine aggregates with copper slag. concrete gain more strength than control mix concrete strength, except 15% replacement of copper slag concrete.
7. The split tensile strength has increased by 14.04% with the use of 40% replacement of fine aggregates with granite powder. concrete gain more strength than control mix concrete strength, except 15% replacement of granite powder concrete

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